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16. ABSTRACT A group of reviewer/experts reviewed evidence and viewpoints reported to date on the issues of ambient oxidant/O ₃ formation and control, and offered their conclusions and recommendations. The reviewers of the stratospheric ozone issue agreed that the stratosphere does not contribute in a major way to the oxidant/O ₃ problem experienced during the smog season. There was consensus also that elevated oxidant/O ₃ concentrations can originate from upwind sources as far as 1,000 km or further. There was no agreement, however, on the details of such oxidant/O ₃ transport. Thus, transport of "fossil" oxidant/O ₃ , transport of precursors, and interaction of transported pollutants with local anthropogenic and/or natural pollutants were proposed specific processes with uncertain relative contributions. Natural emissions were considered as an unimportant source of oxidant/O ₃ , but this judgement was questioned based on indirect evidence. Nearly all reviewers agreed that the scientific evidence obtained since the inception of the first oxidant control strategy does not invalidate the qualitative grounds of that strategy; that is, control of anthropogenic organic emissions continues to be a valid approach to ambient oxidant reduction. There was strong reluctance, however, to endorsing quantitative strategy concepts such as e.g. quantitative assessment of organic emissions based on reactivity, and calculations of numerical control requirements. The majority of reviewers concluded that the ambient oxidant/O ₃ problem requires control of both the hydrocarbon and NO _x emissions.		
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INTERNATIONAL CONFERENCE ON OXIDANT PROBLEMS: ANALYSIS OF THE EVIDENCE/VIEWPOINTS PRESENTED

Part II. Evidence/Viewpoints on Key Issues

Basil Dimitriadis and A. Paul Altshuller
U. S. Environmental Protection Agency

A group of reviewer/experts reviewed evidence and viewpoints reported to date on the issues of ambient oxidant/O₃ formation and control, and offered their conclusions and recommendations. The reviewers of the stratospheric ozone issue agreed that the stratosphere does not contribute in a major way to the oxidant/O₃ problem experienced during the smog season. There was consensus also that elevated oxidant/O₃ concentrations can originate from upwind sources as far away as 1000 km or more. There was no agreement, however, on the details of such oxidant/O₃ transport. Thus, transport of "fossil" oxidant/O₃, transport of precursors, and interaction of transported pollutants with local anthropogenic and/or natural pollutants were proposed specific processes with uncertain relative contributions. Natural emissions were considered as an unimportant source of oxidant/O₃, but this judgment was questioned on the basis of indirect evidence. Nearly all reviewers agreed that the scientific evidence obtained since the inception of the first oxidant control strategy does not invalidate the qualitative grounds of that strategy; that is, control of anthropogenic organic emissions continues to be a valid approach to ambient oxidant reduction. There was strong reluctance, however, to endorse quantitative strategy concepts such as quantitative assessment of organic emissions based on reactivity, and calculations of numerical control requirements. Based mainly on the findings on oxidant transport and on rural oxidant formation, the majority of reviewers concluded that the ambient oxidant/O₃ problem requires control of both the hydrocarbon and NO_x emissions.

In recognition of the importance and somewhat controversial nature of the oxidant control problem, the U.S. Environmental Protection Agency (EPA) organized and conducted a 5-day International Conference in September 1976. The one hundred or so presentations and discussions at the Conference¹ revealed the existence of several unresolved issues, which prompted EPA to sponsor a follow-up review/analysis effort. Specifically, this follow-up effort was to review and analyze carefully and impartially the relevant evidence and viewpoints reported at the International Conference (and elsewhere) and attempt to resolve some of the oxidant-related scientific issues. The first part of the overall effort, described in Part I of this report,² was an explanatory analysis of the problem and definition of key issues, as viewed within the research component of EPA. Following, reviewed here, are the reports of the non-EPA, non-industry expert/reviewer groups offering either resolutions of issues or recommendations for additional research needed to achieve such resolutions. The material presented here constitutes a condensation of these issue reports prepared by these authors with the concurrence of the expert/reviewers, and represents wholly and solely the viewpoint of the expert/reviewers. The uncondensed reports are available in the form of EPA reports.³⁻⁹

The Issue of Reactivity

Reviewers: J. G. Calvert

Ohio State University

H. E. Jeffries

University of North Carolina

Calvert's principal points³ are that (a) presently the smog chamber and computer modeling approaches to evaluating oxidant forming potential of organic air pollutants suffer from certain as yet unsolved problems, and (b) in addition to these two approaches, a third, direct atmospheric studies of chemical changes in ambient atmosphere, should be pursued in parallel. The computer modeling method is presently of uncertain validity mainly because all critical rate constants and the precise composition of air pollutant mixtures in urban and rural air masses are not well known. The smog chamber method is of questionable applicability to the real atmosphere,

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both because the method itself is based on an unproved concept and because the smog chamber data presently available are not easily interpretable in some respects. Thus, the smog chamber walls appear to generate radicals, the source of which may or may not have an equivalent counterpart in the real atmosphere. Likewise, heterogeneous removal of NO_2 may occur only as a smog chamber artifact. Also, of the existing smog chamber data, those on single hydrocarbon- NO_x systems irradiated in the absence of other organics are not necessarily relevant to the real atmosphere situation. Calvert concludes that the "unreactive" organics, working in consort with reactive ones, unquestionably participate in O_3 forming reactions in the atmosphere; however, the quantitative impact of such organics cannot be determined at present. Therefore, classification of organic emissions into "reactives" and "unreactives" may be premature at this time.

Jeffries³ also finds problems with both the smog chamber and computer modeling approaches to evaluating oxidant forming potential of organic emissions. He accepts the Dimitriadis-Joshi contention¹⁰ that the impacts of reactivity related controls cannot be assessed based on air quality data alone; however, he also agrees with Calvert that direct studies of the real atmosphere are crucially needed. Jeffries recommends additional research with objectives (a) to understand and eliminate the artifacts introduced by the smog chamber walls, (b) to determine the stoichiometry of atmospheric reactions of organics, and (c) to obtain additional organic reactivity data by irradiating in a smog chamber each test organic in mixture with other organics and with NO_x .

The Issue of Stratospheric Ozone Intrusion

Reviewers: E. R. Reiter

Colorado State University

V. A. Mohnen

New York State University

Reiter⁴ considers two types of evidence pertinent to the stratospheric ozone issue: (a) evidence derived from analysis of global circulation patterns and, more specifically, from the quantifications of the various mechanisms or processes through which air is interchanged between stratosphere and troposphere; and (b) evidence derived from analysis of data on tropospheric ozone concentration and concentration variation in remote areas.

According to Reiter, air interchange between stratosphere and troposphere occurs via four main mechanisms: mean meridional circulation, fluctuations of tropopause level, stratospheric exchange between hemispheres, and large scale eddies around jet streams. Mean meridional circulation causes a tropospheric O_3 background (of stratosphere origin) to occur at an annual mean concentration of 7 to 17 ppb, and to vary seasonally with peak levels in April-May. Superimposed on such O_3 background are O_3 increments of stratospheric origin caused by large scale eddy mixing ("tropopause folding") and tropopause level fluctuations occurring in the jet stream regions. Such increments have been estimated by Reiter using data on Sr^{90} -related radioactivity in the stratosphere and troposphere and on O_3 concentrations in the lower stratosphere. Thus, stratospheric O_3 intrusion by these processes was estimated to cause a tropospheric O_3 background with an annual mean concentration as high as 12 ppb, and a 24 h average concentration as high as 33 ppb. Assuming the other stratosphere-troposphere interchange processes to have

negligible impact, Reiter estimates the total tropospheric O_3 concentration of stratospheric origin to have an annual mean of 19 to 29 ppb. Occasional intrusions, however, causing considerably higher tropospheric O_3 buildups are also foreseen by theory. Thus, theoretical estimates of dilution attending subsistence of stratospheric O_3 (during tropopause folding events) into the troposphere and into the planetary layer allow for O_3 buildups approaching and even exceeding the federal air quality standard of 80 ppb. The frequency of such strong intrusions was estimated to be on the average of one case per 1 or 2 y or, in terms of days of observations at a given location in middle latitudes, 0.2%.

Reiter feels that stratospheric intrusion evidence based on ground level O_3 measurements should be examined extremely carefully, for it is often obscured or distorted by hidden, interfering factors, e.g., local photochemistry.

Mohnen⁴ also considers the evidence both on stratosphere-troposphere exchange processes and on surface O_3 concentration and concentration variation, but he derives his conclusions mainly from the tropospheric O_3 data. Utilizing the analytical method introduced by Junge,⁴ and data from monitoring stations in remote stations free of local or regional anthropogenic emissions, Mohnen concludes that a range of annual mean concentrations equal to 30 (+5, -8) ppb constitute a representative tropospheric O_3 level (of stratospheric origin) for 35° to 50° N latitude. He also stresses that the tropospheric background O_3 level increases up to ~40 ppb during spring and early summer and declines to ~20 ppb in the late winter due to seasonal variation in stratospheric injection rate. Mohnen also concludes that tropopause folding events can lead to O_3 concentrations at ground level conceivably as high as 150 ppbv and lasting from 2 or 3 hr up to 1 to 3 days. A frequency distribution analysis of O_3 data taken at Whiteface Mountain in 1974 showed that only 0.9% of the hourly concentration values exceeded 80 ppb. The degree to which these high concentrations represent intensive intrusion from stratospheric rather than anthropogenic influences cannot be ascertained with confidence. Strong evidence suggests, however, that the source of such O_3 lies aloft and that O_3 is brought down with descending air masses. According to Mohnen, the Whiteface Mountain data analysis is in reasonable agreement with Reiter's conclusion regarding the frequency of intensive stratosphere intrusion events (0.9% versus 0.2%).

The Issue of Natural Organic Emissions

Reviewers: P. E. Coffey

State of New York

H. Westberg

Washington State University

Coffey⁵ proposes a regional "ozone-blanket" theory to explain similarities between urban and rural areas in patterns of episodic O_3 concentrations for the northeastern U.S. Ozone concentrations observed within urban areas probably result from advection and mixing of such upwind regional O_3 . Diurnal concentration patterns can be explained as a result of O_3 destruction by nitric oxide during night and early morning hours, followed by advection and downward mixing of regional O_3 during the later morning hours. Besides such downward infusion, horizontal transport of photochemically formed O_3 from upwind sources also appears to contribute to the O_3 problem within urban areas. Thus, urban emissions create problems within their source areas only indirectly,

through regional O_3 formation; their direct impact is observed in downwind areas as far away as 160 km or more.

Potential sources of regional O_3 according to Coffey are the stratosphere, photochemistry of natural emissions, and photochemistry of anthropogenic emissions from the urban and rural sources within the "blanketed" region. The relative importance of each source is not well established, it may be different for different regions. Based on ^7Be activity measurements, the stratospheric source does not seem to contribute in a major way to regional O_3 . In contrast, anthropogenic emissions from both large and small urban areas within the region are clearly a major O_3 source. Coffey feels that the relative importance of the natural emissions as a source of regional O_3 has not been determined reliably. Natural emission inventories have been estimated but are not readily interpretable. For example, data on annual emission rates underestimate the true relative importance of the natural emissions during the smog season. This is because the anthropogenic emissions are emitted at a fairly uniform rate during the year, whereas the natural emissions occur mostly during the smog season. Coffey maintains that, although direct evidence is lacking, it would be difficult to explain all observations on oxidant/ O_3 occurrence without assuming a significant role for the natural organics.

Westberg's review/analysis⁵ focuses on the importance of natural organics as a source of ambient oxidant/ O_3 , basing his judgment on existing evidence on emission rates, ambient concentrations, and photochemical reactivities of natural organic emissions. His estimate of the natural emission level during the summer months is ~85% of the natural plus anthropogenic total. Despite such emission predominance, however, atmospheric dilution and reactions prevent natural organics from accumulating to concentrations greater than a few ppbC—a conclusion which is supported by existing measurements on ambient terpenes. Furthermore, terpene reactivity data obtained from smog chamber tests suggest that, under the low ambient concentration and high hydrocarbon-to- NO_x ratio conditions prevailing in non-urban areas, the terpenes are incapable of forming significant levels of oxidant/ O_3 . Westberg's conclusion is that the evidence obtained and reported to date does not support a significant role for the natural organic pollutants in the ambient oxidant/ O_3 problem. Oxidant/ O_3 occurrence can be explained plausibly either in terms of photochemistry of anthropogenic emissions, locally emitted or transported in, or in terms of stratospheric ozone intrusion.

The Issue of Oxidant Transport

Reviewers: E. Robinson

Washington State University

F. M. Vukovich

Research Triangle Institute

D. H. Pack

Consulting Meteorologist

Robinson⁶ focuses mainly on the impact of oxidant/ O_3 transport on rural and urban air quality relative to the impact of natural oxidant sources. He concludes that the dominant cause of elevated (>80 ppb) oxidant/ O_3 concentrations observed in rural areas is transport of anthropogenic pollutants. Extensive field studies by Research Triangle Institute (RTI) and others have shown that in the Gulf Coast and Texas and in the Midwest states east and southeast of the Dakotas high

ozone levels over wide (urban and rural) areas are associated with weak winds with trajectories indicative of flow in a high pressure system. He stresses RTI findings that suggest that an air parcel and its entrained pollutants do not travel as a permanent part of a high pressure system. Instead, the parcel moves in on one side of the system and out on the other as the high pressure cell moves across the area. Oxidant transport associated with such air movement varies in range and intensity depending on wind speed and sunlight conditions and on the strength of the emission sources within the wind trajectory areas. Optimum wind speed (to effect longest transport with minimum dilution) and high emission density are obvious requirements for long range transport. Such transport should involve both O_3 and the O_3 precursors. Precursor transport, unlike O_3 transport, cannot be demonstrated at this time to occur over such long distances. This situation probably results from analytical problems in measuring precursors.

Besides such long range (several hundred kilometers) transport associated with stagnating warm anticyclones, Robinson also recognizes shorter range oxidant transport in the form of urban oxidant plumes. Such plumes have been observed to stretch downwind to distances of at least 160 km for St. Louis and 400 km for New York City. Dispersion of such urban plumes into a regional atmosphere will have varying impact depending on the nature of the background pollutants. Thus, in the midwest, where background pollutants are predominantly of anthropogenic origin, the incremental impact of an urban plume should be smaller compared to the impact in an atmosphere with a biogenic pollutant background, e.g., Montana.

Robinson suggests that the oxidant/ O_3 transport phenomenon has both similarities and differences in characteristic patterns, causes, and effects, in the various regions of the United States. For example, relative to the midwest and the Gulf Coast areas, weather patterns in the northeast seem to play a lesser role in establishing oxidant/ O_3 levels. Robinson recognizes that the general levels of oxidant/ O_3 reflect the general weather patterns, but he sees a much broader set of weather conditions accompanying occurrences of high oxidant/ O_3 levels in the northeast, and less sensitivity, for example, to the location or intensity of a high pressure system. This could be a result of the high population density in that area and the relative dominance of urban plumes over the anthropogenic background pollutant levels in the air.

On the question of impact of pollutants from upwind sources on an urban oxidant problem, Robinson feels that such impact cannot be quantitated with confidence at this time. Estimates of such impacts derived from meteorological and chemical models are crude; nevertheless they may be as useful as any except those derived from the most comprehensive field studies.

Vukovich's analysis⁶ is centered around the credibility of two conceptual models or mechanisms explaining elevated O_3 concentrations in locations remote from sources. One model suggests that direct transport of O_3 is the principal mechanism; the other model suggests transport of O_3 precursors. Vukovich favors the latter one.

In his analysis, Vukovich recognizes two predominant scales of oxidant/ O_3 transport: (a) The mesoscale transport observed mainly in the form of urban pollution plumes moving downwind from urban areas (also encompassing urban heat island circulation and land and sea breeze circulation); and (b) synoptic scale transport that appears to be associated with high pressure systems. Of these, the urban plume situation is relatively simple and clear. Thus, direct transport of O_3 is certain to occur. Further, the fact that maximum oxidant/ O_3 concentrations have been observed to occur downwind from urban centers indicates that precursor transport and concurrent photochemical production of oxidant/ O_3 also must occur, since a meteorologically induced mass-convergence is unlikely.

Oxidant/ O_3 transport associated with synoptic meteorology is less simple. Such transport has been proposed to explain occurrence of elevated oxidant/ O_3 concentrations over large rural areas. According to other investigators, such as Coffey¹¹ and Dobbins et al.,¹² the principal specific mechanism explaining such occurrence entails direct transport of oxidant/ O_3 from oxidant/ O_3 -rich layers aloft to the surface. Vukovich is not in complete agreement with this mechanism and explanation. He cites the fact that more significant vertical mixing occurs in low pressure systems, yet no statistical correlation exists between high rural oxidant/ O_3 and low pressure systems. Furthermore, many of the more recent vertical O_3 profiles taken in high O_3 rural situations cannot be explained by vertical transport alone. By the process of elimination based on existing evidence, Vukovich concludes that photochemical generation is the most probable mechanism responsible for the high oxidant/ O_3 in the rural boundary layer.

Vukovich concludes further that an important difference exists between the photochemical process associated with synoptic scale transport and the process that accompanies the shorter scale, urban plume type transport. In the latter case, the photochemical reaction involves mainly the more reactive organics (and nitrogen oxides) and results in rapid formation of oxidant/ O_3 ; this explains the downwind high oxidant/ O_3 in urban plumes. In the case of synoptic scale transport, the morning air parcel loses the more reactive precursors more rapidly than the less reactive ones. After several days of such transport, and in the presence of sufficient sunlight, the remaining bulk of the less reactive precursors reacts and produces oxidant/ O_3 . This, combined with oxidant/ O_3 production from the more reactive precursors collected daily, causes the air parcel to contain large concentrations of oxidant/ O_3 . Such multiday transport and attendant consequences can impact areas as far away from the source as 1000 km or more. The basic conclusion of Vukovich's analysis is that the most important mechanism for producing high oxidant/ O_3 in the rural boundary layer on any scale is the transport of oxidant/ O_3 precursors from anthropogenic and natural sources combined with photochemical generation. This factor is most important on the synoptic scale in the eastern portions of the U. S. and on the mesoscale immediately downwind of any urban area.

Pack's review/analysis⁶ is in direct response to the specific questions raised in the EPA definition of the oxidant/ O_3 -related issues.² Thus, he contends that long distance transport of anthropogenic oxidant/ O_3 has been convincingly demonstrated to occur over distances up to about 1000 km. Transport over the longest distances requires minimal near-surface destruction of oxidant/ O_3 . Such destruction is minimized when the transported air masses move above a protective surface inversion "barrier," when the surface is less "destructive" or when no significant concentrations of oxidant/ O_3 -destroying compounds are present. Under such minimal destruction conditions, the O_3 lifetime may be as long as 2 to 3 days.

Pack agrees with the previous reviewers that high episode levels of oxidant/ O_3 are related to anticyclonic weather systems moving over areas with significant emission density. The time scale of such meteorological events is of the order of 2 to 3 days at a fixed point, but the total effect of the moving weather system may be 2 to 3 times as long as it successively affects different areas. According to Pack the data are insufficient to separate the contributions of "fossil" oxidant/ O_3 from fresh oxidant/ O_3 formed from unreacted oxidant precursors in the second and succeeding days of high oxidant episodes. The transport of precursors has not been adequately verified, but the scanty evidence favors such a phenomenon. Pack suggests an experimental configuration to permit following and measuring a parcel of air as the most direct and

feasible way to determine atmospheric reaction and destruction rates for oxidant/ O_3 and to study the (probably variable) inventories of O_3 -related compounds. Such an approach would facilitate understanding of mechanisms, especially of the O_3 destruction and vertical mixing by the atmosphere.

The Issue of Current Air Quality Simulation Utility

Reviewers: J. H. Seinfeld

California Institute of Technology

K. R. Wilson

University of California, San Diego

Seinfeld's analysis⁷ represents an attempt to assess the degree of accuracy of current air quality simulation models (AQSM). His analysis is centered around the absolute and relative performance of four AQSM's chosen among those relatively more comprehensively described and tested and in wider use. The AQSM's chosen were the ones developed by Systems Applications, Inc. (SAI), Lawrence Livermore Laboratory (LIRAQ), Environmental Research and Technology (DIFKIN), and Bell Laboratories. They include two and three dimensional grid models, a trajectory model, and a box model, each having different degrees of chemical and dispersive detail. Of the AQSM's examined, Seinfeld suggests that the SAI and LIRAQ models represent reasonable compromises between chemical detail and computational tractability. The Bell Laboratories model, on the other hand, is noted by Seinfeld to have inappropriate chemical detail when compared with its lack of meteorological detail.

Seinfeld's analysis also includes estimates of model prediction errors arising from uncertainties in the conceptual bases of the AQSM (i.e. with the atmospheric diffusion equation) and from errors in the input information (e.g. chemical mechanism, wind field, mixing height, emission rates, etc.). Seinfeld's analysis resulted in an overall estimated level of uncertainty in absolute levels of oxidant predictions equal to $\pm 50\%$, the uncertainty in predictions of relative changes in oxidant levels being somewhat less. Seinfeld does not address the question of whether such uncertainty is tolerable or not. Nevertheless, he does submit that the AQSM's have reached a level of detail wherein major new chemical or physical changes are unlikely. He also maintains that either smog chamber data or AQSM are more representative of atmospheric phenomena than is the Appendix J curve, and that AQSM's represent ultimately the preferred procedure for oxidant prediction. He notes that the Dimitriadis method,¹³ based on smog chamber data (or a chemical mechanism), represents a compromise between the purely empirical Appendix J curve and the fundamentally based AQSM's. He recommends that a comparative study of the SAI and LIRAQ models with the Dimitriadis method be carried out to ascertain the differences in the O_3 concentrations predicted by the two methods as a result of the inclusion of transport and continuous emissions in the AQSM's.

Wilson⁷ concludes that none of the several alternative approaches to predicting oxidant/ O_3 levels from precursor emissions is capable of the accuracy which is desirable in

evaluation of urban oxidant control strategies, although each approach is useful in the proper context. Rollback is arbitrary; Appendix J is statistically unsound; statistical models are uncertain outside the range of the data used to develop them; smog chamber simulations leave out the effects of transport, mixing and turbulent inhomogeneity and, in addition, involve approximations in chemical kinetics and small scale motions which lead to errors. Thus, the utility of AQSM's, like other approaches, needs to be evaluated in the context of a particular application. Wilson's view is that AQSM's are essential for scientific understanding of photochemical air pollution and that they are probably useful for the choice among emission control alternatives, as long as they are not used to set absolute goals. AQSM's appear only marginally useful for monitoring station siting and "their use is judged to be most unwise as legal standards."

The Issue of Oxidant/O₃ Measurement

Reviewers: J. N. Pitts

University of California, Riverside

G. Su

State of Michigan

Pitts' review/analysis⁸ is in direct response to questions proposed by EPA on the oxidant/O₃ measurement issue.² On the question regarding the impact of the precision/accuracy errors on the validity of the Federal Reference Method for oxidant/O₃, Pitts submits that such errors do invalidate the Federal method. For calibration of O₃ monitors, Pitts recommends use of either the UV method or gas-phase titration; for monitoring he considers both the UV and chemiluminescence techniques to be acceptable although somewhat expensive. Pitts recommends that past KI measurements of oxidant be corrected if possible for NO₂ and SO₂ interferences. Also, besides specific measurements of O₃, NO₂, and SO₂, future monitoring should also include KI measurements of oxidant for the purpose of correlating current and future oxidant/O₃ data with those obtained, for example, in the 1960's. In response to the question on the impact of the response specificity error, Pitts believes that if one monitors ambient oxidant with an O₃ specific instrument but conducts health effects studies in which total oxidant is measured, then the two data sets cannot be effectively related. Pitts does not offer an alternative (specific) method for oxidant/O₃; he stresses, instead, that the "analytical monitoring techniques used to determine human exposure to O₃ or oxidant in the laboratory must be entirely consistent with the analytical monitoring techniques used to determine human exposure to O₃ or oxidant in real ambient air." To the question regarding the impact of analytical method imperfections on the validity of the air quality standard for oxidant/O₃, Pitts offers conditional answers. The Pitts viewpoint, in brief, is that for the standard to be valid, the measurements for determining levels of exposures of humans to O₃ or oxidant in both the laboratory and in ambient air should be self-consistent.

Su,⁸ in his review/analysis, expresses his conviction that the (neutral buffered) KI method is unacceptable because it yields erroneously high and often nonreproducible results. Su recommends that EPA withdraw the KI method as a reference method and accept UV photometry and gas phase titration as reference calibration methods.

The Issue of the Optimum Oxidant/O₃ Control Strategy

Reviewers: P. Kozlar and B. Becker

State of Wisconsin

W. K. Bonta and J. W. Paisie

State of Maryland

G. T. Wolff

Interstate Sanitation Commission (NY, NJ, CT)

L. E. Jager

State of Michigan

F. Spuhler and K. Waid

State of Texas

Kozlar and Becker⁹ address their review/analysis first to the relative roles of the natural and the anthropogenic emissions, then to the questions proposed by EPA as constituting the oxidant control strategy issue.² On the role of the natural emissions, they conclude that while stratospheric O₃ and oxidant/O₃ from natural emissions photochemistry can cause O₃ concentrations exceeding 0.08 ppm in some cases, anthropogenic emissions are mainly responsible for the highest oxidant/O₃ concentrations recorded at ground level.

Kozlar and Becker interpret the field and laboratory studies reported to date to mean that the qualitative roles of the hydrocarbon precursors and more specifically, the directional effect of hydrocarbon control on oxidant/O₃ are well established; they therefore conclude that adoption of unilateral hydrocarbon control as the optimum oxidant/O₃ control strategy continues to be justified. Unlike hydrocarbon, the evidence available on the effect of NO_x reduction is rather incomplete and has unclear control implications. In addition to the scientific bases, Kozlar and Becker favor hydrocarbon control also on grounds related to emission control technology and emission control history. Thus, hydrocarbon control technology is much more advanced than that for NO_x control, and large reductions in hydrocarbons could be effected within a reasonable time frame as a result of controls already in use.

Regarding the quantitative aspects of the oxidant/O₃ control strategy, Kozlar and Becker offer a comparative analysis of the four alternative approaches suggested by EPA² to quantify the relationships between urban emissions and ambient oxidant. By approaches I and III, the maximum oxidant/O₃ observed in an urban area is viewed as related to local-plus-extraneous and local emissions, respectively.² By approaches II and IV, the pertinent cause-effect relationships are viewed as being between local emissions and the fractional oxidant concentration attributable to local emissions.² Kozlar and Becker favor approach IV. This is the approach that calls for estimation of the fractional oxidant concentration attributable to local emissions and, unlike approach II, also calls for emissions control sufficiently stringent to offset oxidant/O₃ formation from extraneous emissions. Kozlar and Becker further recommend refinements of this approach (a) by including a requirement of monitoring data upwind and downwind of cities, (b) by setting an oxidant/O₃ goal of 0.06 ppm for urban areas, and (c) by including the provision that no local hydrocarbon control be required in urban areas where the fractional oxidant/O₃ concentration attributable to local emissions is less than 0.02 ppm.

Bonta and Paisie⁹ examine and interpret the presently available evidence in terms of short-term and long-term im-

pacts of emissions controls upon both urban and rural oxidant-related air quality. They conclude that the short-term impact of organic and NO_x emissions reduction may not be a concomitant reduction in ambient oxidant. With respect to long-term impact, they conclude that the recent evidence supports that the role of the organic emission factor continues to be one of promoting oxidant formation, at least in urban areas. The oxidant concentration and emission trends observed within some urban areas are consistent with such an organic emission role but only qualitatively. Quantitative associations are not possible because the effects upon oxidant of the organic emissions reduction cannot be separated from the codirectional effect of the NO_x emission increase. Based on their interpretation of the overall evidence, Bonta and Paisie conclude that positive control of urban organic emissions is necessary and recommend that it be continued. They further recommend, until new, more definitive evidence is obtained, that EPA continue to endorse the control policy based on the assumption that the emissions within an urban area are wholly and solely responsible for the oxidant problem in that urban area.

In regard to the NO_x emissions role, Bonta and Paisie believe that control of urban NO_x is counterproductive when urban oxidant is of concern. Increase in urban NO_x emissions, however, also is detrimental as it enhances transport of NO_2 into the rural areas and hence can contribute to higher rural oxidant levels. The best policy, therefore, is to maintain urban NO_x emissions at their current levels. Finally, unlike the roles of the urban emissions in the urban and rural oxidant problems, Bonta and Paisie believe that the roles of the emissions released in the rural areas are not clear at this time. Therefore, until more information is available, they recommend that control of rural emissions be held in abeyance.

With respect to future efforts needed, Bonta and Paisie recommend development of an air quality simulation model for oxidant/ O_3 that would include treatment of interactions between urban and rural pollutants, of the role of natural precursor emissions, and of stratospheric O_3 effects. They also point to the need for a much more effective coordination of multiregion and multistate oxidant abatement strategies.

The Wolff review/analysis⁹ deals successively with the justification of the need for anthropogenic emission control and with the relative impacts of hydrocarbon and NO_x emission controls upon urban and rural oxidant/ O_3 . Based mainly on aerometric data analyses performed by a multistate study group¹⁴ (Moodus Conference group), Wolff concludes that high oxidant/ O_3 episodes associated with high pressure systems in the midwest and northeast are most likely caused by anthropogenic emissions. Wolff also finds ample evidence, from laboratory, modeling, and field studies, supporting the conclusion that hydrocarbon control continues to be a valid approach to urban oxidant/ O_3 reduction. On the question of the NO_x role, Wolff interprets a considerable amount of reported evidence to mean that control of urban NO_x will result in a local increase of oxidant/ O_3 but will have a beneficial impact upon the areas downwind. Because of this downwind effect of NO_x control and because the oxidant-related air quality in a locality (urban or rural) can be affected significantly by the emissions hundreds of miles upwind, Wolff concludes that reduction in NO_x will result in an overall reduction of ozone.

Jager⁹ also finds that in spite of the possibly significant contributions of the natural sources of oxidant/ O_3 , control of anthropogenic organic emissions continues to be a valid oxidant/ O_3 control strategy. For reasons similar to those discussed by Wolff, Jager also concludes that control of NO_x emissions, both in urban and rural areas, is desirable. On the question of quantitative relationships between oxidant/ O_3 and emissions, Jager submits that the pertinent scientific evidence presently available is uncertain to a degree such that it would be unwise to develop and enforce oxidant/ O_3 control strategies

based on quantitative relationships; instead, a "maximum reasonable control" policy should be adopted as more justifiable. Further, because of the occurrence of inter-state pollutant transport, such a policy should be implemented in the form of regional (multistate) control plans, as needed, rather than on a state-by-state basis.

Spuhler and Waid,⁹ citing extensively a National Academy of Sciences report¹⁵ and Part I of this report,² conclude that the optimum control strategy for oxidant/ O_3 should include control of both hydrocarbon and NO_x and should also "address all [other] precursors to oxidant formation." Spuhler and Waid conclude further, that application of reasonable available control technology (to both organic and NO_x emissions) is at present the only feasible control policy since quantitative emissions-to-air quality relationships and emission control requirements cannot be obtained at this time.

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